Updated Z-Corrections for 64-m DSS Ground Station Delay Calibrations

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This article presents new Z-corrections which resulted from recent translator path delay calibrations made at DSS 14, 43, and 63 with newly developed DSN Portable Zero Delay Assemblies.

I. Introduction

In recent months, new Portable Zero Delay Assemblies (PZDA) were developed for the DSN (Ref. 1). These PDZAs were shipped to DSS 14, 43, and 63 for purposes of making calibrations of the Block IV translator paths. Each of the 64-m antenna stations is now equipped with its own calibrated PDZA and is therefore capable of making translator path delay calibrations upon request.

The purpose of this article is to provide the necessary information and data required by Network Operations to make future Z-correction calculations based upon the translator delay values furnished by each 64-m Deep Space Station. It is also the purpose of this article to show that the technology for the "Translator Method" (Ref. 2) has been successfully transferred to Network Operations.

II. Z-Correction Equation

As discussed in Ref. 2, Z-corrections are necessary for correcting the measured ground station delays and referring them to the DSS reference location. This information is needed for determining the true range to the spacecraft. The Z-corrections for 64-m Deep Space Stations are determined from the basic equation derived in Ref. 2 for the Block 4 Translator Method. This equation is:

$$Z = \tau_{XLTR} - \sum_{i=3}^{6} \tau_i \qquad (1)$$

where τ_{XLTR} is the delay of the translator path between the uplink sampling point and the downlink injection point. The term τ_3 is the microwave delay from the uplink sampling point to the transmit horn phase center and τ_4 is the microwave delay from the receive horn phase center to the downlink injection point. The terms τ_5 and τ_6 are, respectively, the uplink and downlink airpath delays from the horn phase centers to the DSS reference location via the convoluted Cassegrain antenna optics paths. These terms are defined more clearly and precisely in Ref. 2.

As may be seen in Eq. (1), one of the terms needed to determine the Z-correction is the translator path delay τ_{XLTR}. This term includes the delays of the Level Set Attenuator Assembly, Block IV Translator Assembly, Test Signal Control Assembly, and interconnecting cables. Because of the complexity of this path, this delay is measured rather than calculated.

The procedure for the measurement of τ_{XLTR} has been described previously in Refs. 3 and 4 and repeated here for convenience. A portable Zero Delay Device (ZDD) and its cables are substituted for the Block IV translator path and the range delay R_{ZDD} is measured. Then the *ZDD* cables are inserted in series with the Block IV translator path and the range delay is again measured and denoted as R_{XLTR}. The measured translator delay is calculated from (see Ref. 3 for derivation)

$$(\tau_{XLTR})_m = R_{XLTR} - R_{ZDD} + \tau_{ZDD} \tag{2}$$

where τ_{ZDD} is the delay of the portable *ZDD* without its external cables. This value of τ_{ZDD} is known and had been precisely precalibrated in the laboratory. For future reference purposes, the values of τ_{ZDD} for the PDZA at each 64-m DSS is tabulated in Table 1. It should be pointed out that the terms R_{ZDD} and R_{XLTR} in Eq. (2) are symbols used in DSN test procedures. They are the same as the terms D_{ZDD} and D'_{XLTR} defined in Refs. 3 and 4.

Equation (2) results in a measured value of the translator path between coaxial connection points to which the *ZDD* cables can be conveniently connected. This is the value furnished by the station using DSN Test Procedures 853-100. However, the actual translator path must be defined internal to the waveguide system to points common to the "range on S/C path." Therefore, small corrections need to be applied to the measured values for the additional lengths of coax to waveguide paths involved. The true translator path delay is determined from the expression

$$\tau_{XLTR} = (\tau_{XLTR})_m + \tau_{WG,up} + \tau_{WG,down} \tag{3}$$

The term $\tau_{WG,up}$ is a small correction term needed to go from the actual measurement uplink sampling point to the same point where τ_3 is defined. The term $\tau_{WG,down}$ is a small correction term needed to go from the actual measurement downlink sampling point to the same point where τ_4 is defined.

The current values of constants needed to calculate Z-corrections from Eqs. (1) and (3) are tabulated in Table 2. It should be pointed out that the S-band constants at DSS 14 are different from those of DSS 43 and 63 because of a dual coupler configuration which was implemented in June 1977. The terms τ_3, τ_4, τ_{XLTR} at DSS 14 are defined at a common reference plane where the WR430 flange on the dual coupler assembly connects to the WR430 switch SW3. The terms $\tau_{WG,up}$ and $\tau_{WG,down}$ are the delays between the coaxial sampling-injection ports on the dual coupler and the described common reference plane. For the X-band downlink path, τ_4 and τ_{XLTR} are defined up to the midpoint of the X-band waveguide coupler installed directly in front of the XRO maser. For X-band the last coaxial connection point is the input to the XRO noise box, and the correction term $\tau_{WG,down}$ is the additional delay of the waveguide run through the XRO noise box assembly to the midpoint of the X-band waveguide coupler.

At DSS 43 and 63, τ_{XLTR} for the (S,S) path is defined between a high-power WR430 coupler (located in the Mod III Section) and the midpoint of a WR430 crossguide coupler installed in front of the SPD maser. At these two overseas stations, the term $\tau_{WG,up}$ value is assumed to be negligibly small. The term $\tau_{WG,down}$ for S-band is the small (but non-negligible) delay between (1) a 7/8 coaxial port on the 7/8-to-WR430 transition connected to the SPD maser WR430 crossguide coupler and (2) the midpoint of the SPD maser crossguide coupler. The $\tau_{WG,down}$ value for X-band is defined between the same points described above for DSS 14.

The constants given in Table 2 may undergo changes in the future if any changes are made in the S/X feed system for the SPD and XRO cones. It is expected that if new configurations affect these tabulated constants, the JPL section responsible for the redesign and implementation will provide new values to Network Operations.

III. Measured Values

During the period of May through July 1978, at the request of Network Operations, measurements were made by the 64-m stations to calibrate the translator path delays using the new PDZAs. Some difficulties were experienced at some of the stations, and therefore reliable test data was not obtained until July 31. The test procedures have since been revised to help overcome some of the problems experienced by station personnel.

The final measured translator path delays and new Z-corrections for DSS 14, 43, and 63 are presented in Tables 3-5. The Z-corrections are average values for the frequencies of Channels 5 through 25. (The relationship of channel numbers to frequency may be found in Table 1 of Ref. 3.) It should be pointed out that at both DSS 14 and DSS 43, the Z-correction for X-band appears to be frequency-sensitive. For critical experiments involving interstation ranging comparisons, it is recommended that instead of using the average X-band value, Z-corrections be determined specifically for the channel frequencies involved. All of the necessary values for recalculating Z-corrections at a particular channel are supplied in this article.

For comparison purposes, the old and new translator path delays and Z-corrections for all 64-m DSS are shown in Table 6. Examination of the data for DSS 14 shows that the old and new Z-correction values agree to within 0.2 m at both S- and X-band. For DSS 43 and 63, the old and new Z-correction values agree to within 2.2 m at S-band and ±1.0 m at X-band. Causes of the disagreement for DSS 43 and 63 values are difficult to determine. It is possible that since the calibrations at these two overseas stations were last performed about 2.5 years ago, cable and component changes might have been made in the translator paths without our knowledge*. At DSS 14, the last calibration was performed about 1 year ago and the configuration remained basically unchanged. It is recommended that Network Operations have these calibrations performed more often (on a 6-month periodic basis) or whenever a major known configuration change is made in the translator path.

*After submitting this article for publication, investigations made of past ECOs revealed that new cables and components had been added to the (S,S) translator path at the overseas stations. These additions account for most of the changes observed in the (S,S) translator path values shown in Table 6.

IV. Concluding Remarks

New Z-corrections for 64-m stations have been derived. These new values are based upon translator path delay measurements made with a new PDZA supplied to each 64-m DSS. In the case of DSS 14 measurements, the values of old and new Z-corrections agreed within 0.2 m. Considering that the old values at DSS 14 were obtained with the use of an R&D portable ZDD and new values were obtained with a DSN PDZA having different cables and internal mixers and components, the results are very encouraging and lend confidence to the measurement technique.

The test results indicate a successful transfer of technology from development to implementation and finally to the operations phase. Each 64-m station is now capable of making these measurements upon request, and constants have been supplied to Network Operations for making future Z-correction calculations. It is recommended that Z-correction determinations be repeated on a periodic 6 month basis.

References

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Table 1. Calibrated delays for DSN portable zero delay assemblies

DSS	Serial number	τ_{ZDD}, ns (S,S) path	τ_{ZDD}, ns (S,X) path
14	2	18.84	14.28
43	3	18.13	14.18
63	4	18.24	13.93

Table 2. Constants for Z-correction calculations

DSS	$\tau_{WG,up}$, ns	$\tau_{WG,down}$, ns	τ_3, ns	τ_4, ns	Airpath τ_5, ns	Airpath τ_6, ns
(S,S) path[a]						
14	0.42	0.41	22.18	19.66	102.56	102.56
43	–	1.05	62.00	45.44	102.56	102.56
63	–	1.05	62.00	45.44	102.56	102.56
(S,X) path[b]						
14	0.42	6.01	22.18	5.34	102.56	93.42
43	–	6.01	62.00	5.34	102.56	93.42
63	–	6.01	62.00	5.34	102.56	93.42

[a] DSS 14 only has the dual coupler configuration. The constants for DSS 14 are the same as given in Ref. 4.

[b] Some of the values for DSS 43 and 63 have been changed from previously reported values in JPL internal memos because of improved S- and X-band horn delay values and XRO cone updates at the overseas stations.

Table 3. DSS 14 calibrations (July 30, 1978)

Measured translator path delays

Channel	$(\tau_{XLTR})_m$, ns (S,S) path	$(\tau_{XLTR})_m$, ns (S,X) path	Comments
5	203.7	173.7	S-band measurement corrected for missing cable
9	204.0	168.5	
14	206.4	170.3	
17	209.0	173.0	
21	206.7	170.0	
25	207.1	158.4	X-band delay is about 10 ns shorter than average
Average	206.15 ±0.82(1σ)	168.98 ±2.26(1σ)	

Corrected translator path delays and Z-corrections

Path	Average $(\tau_{XLTR})_m$, ns	$\tau_{WG,up}$, ns	$\tau_{WG,down}$, ns	τ_{XLTR}, ns	$\sum_{i=3}^{6} \tau_i^a$, ns	Z, ns	Z, m
(S,S)	206.15	0.42	0.41	206.98	246.96	−39.98	−5.99
(S,X)	168.98	0.42	6.01	175.41	223.50	−48.09	−7.21

[a]See Table 2.

Table 4. DSS 43 calibrations (May 26, 1978)

Measured translator path delays

Channel	$(\tau_{XLTR})_m$, ns (S,S) path	(S,X) path	Comments
5	181.1	183.8	
9	184.8	186.6	
14	$\begin{bmatrix}184.7\\185.6\end{bmatrix}$	$\begin{bmatrix}179.8\\181.7\end{bmatrix}$	
18	185.5	175.9	Delay at X-band is about 5.6 ns lower than average
21	189.2	178.7	
25	187.2	184.2	
Average	185.44 ±0.94(1σ)	181.53 ±1.39(1σ)	

Corrected translator path delays and Z-corrections

Path	Average $(\tau_{XLTR})_m$, ns	$\tau_{WG,up}$, ns	$\tau_{WG,down}$, ns	τ_{XLTR}, ns	$\sum_{i=3}^{6} \tau_i$[a], ns	Z, ns	Z, m
(S,S)	185.44	–	$\begin{bmatrix}1.05\\+\ 2.93^{b}\end{bmatrix}$	189.42	312.56	–123.14	–18.46
(S,X)	181.53	–	6.01	187.54	263.32	–75.78	–11.36

[a]See Table 2.

[b]Actual measurement point used was not as specified in DSN test procedures. Therefore additional correction of 2.93 ns was required.

Table 5. DSS 63 calibrations (May 10, 1978 and July 31, 1978)

Measured translator path delays

Channel	$(\tau_{XLTR})_m$, ns (S,S) path	$(\tau_{XLTR})_m$, ns (S,X) path	Comments
5	184.1	173.6	
9	187.8	174.0	
14	[193.3] [186.7]	[170.7] [171.0]	Second row numbers at this channel are from the May 10, 1978, measurement
17	188.5	171.5	
21	188.4	171.6	
25	192.1	169.2	
Average	188.70 ±1.18(1σ)	171.66 ±0.63(1σ)	

Corrected translator path delays and Z-corrections

Path	Average $(\tau_{XLTR})_m$, ns	$\tau_{WG,up}$, ns	$\tau_{WG,down}$, ns	τ_{XLTR}, ns	$\sum_{i=3}^{6}\tau_i$[a], ns	Z, ns	Z, m
(S,S)	188.70	–	1.05	189.75	312.56	-122.81	-18.41
(S,X)	171.66	–	6.01	177.67	263.32	-85.65	-12.84

[a]See Table 2.

Table 6. Comparisons of old and new values of corrected translator path delays and Z-corrections for 64-m DSS

DSS	Band	τ_{XLTR}, ns	Z, ns	Z, m	Approx. date of calibration
			Old values		
14	S	208.13	−38.83	−5.82	June 15, 1977
	X	174.83	−48.67	−7.30	
43	S	176.95	−136.37	−20.46	Dec. 3, 1975
	X	'183.41	−81.17	−12.18	Dec. 19, 1975
63	S	176.02	−137.30	−20.60	Jan. 20, 1976
	X	184.31	−80.27	−12.04	
			New values		
DSS	Band	τ_{XLTR}, ns	Z, ns	Z, m	Date of calibration
14	S	206.98	−39.98	−5.99	July 30, 1978
	X	175.41	−48.09	−7.21	
43	S	189.42	−123.14	−18.46	May 26, 1978
	X	187.54	−75.78	−11.36	
63	S	189.75	−122.81	−18.41	July 31, 1978
	X	177.67	−85.65	−12.84	